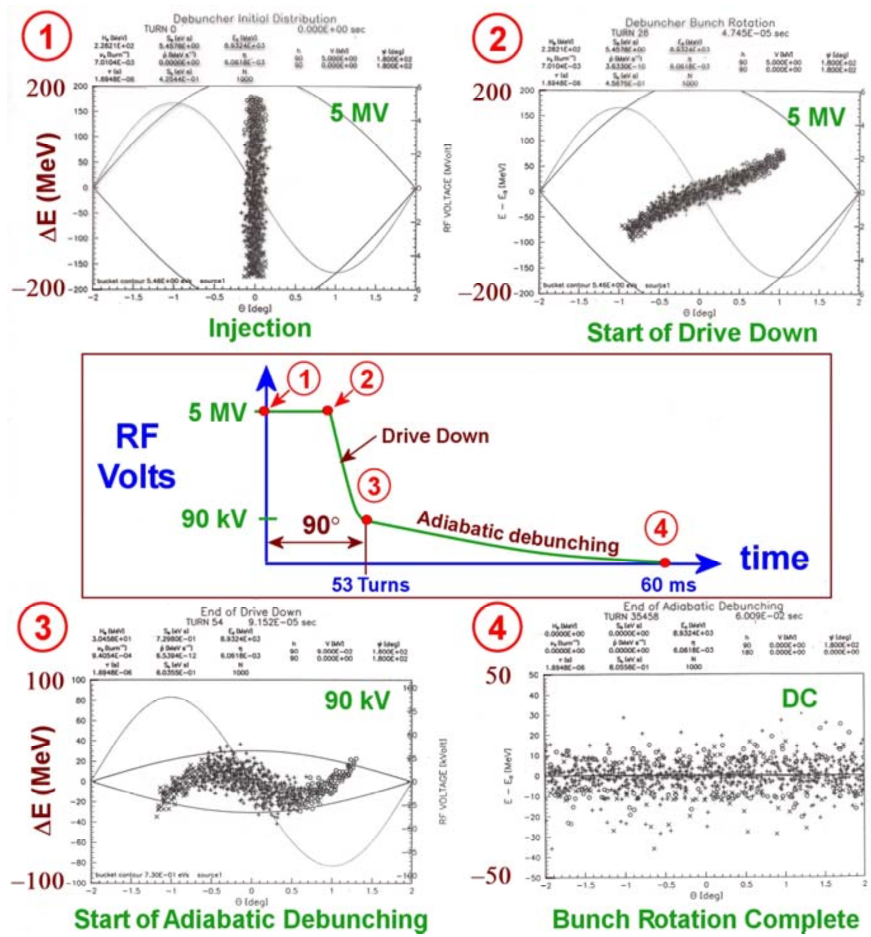
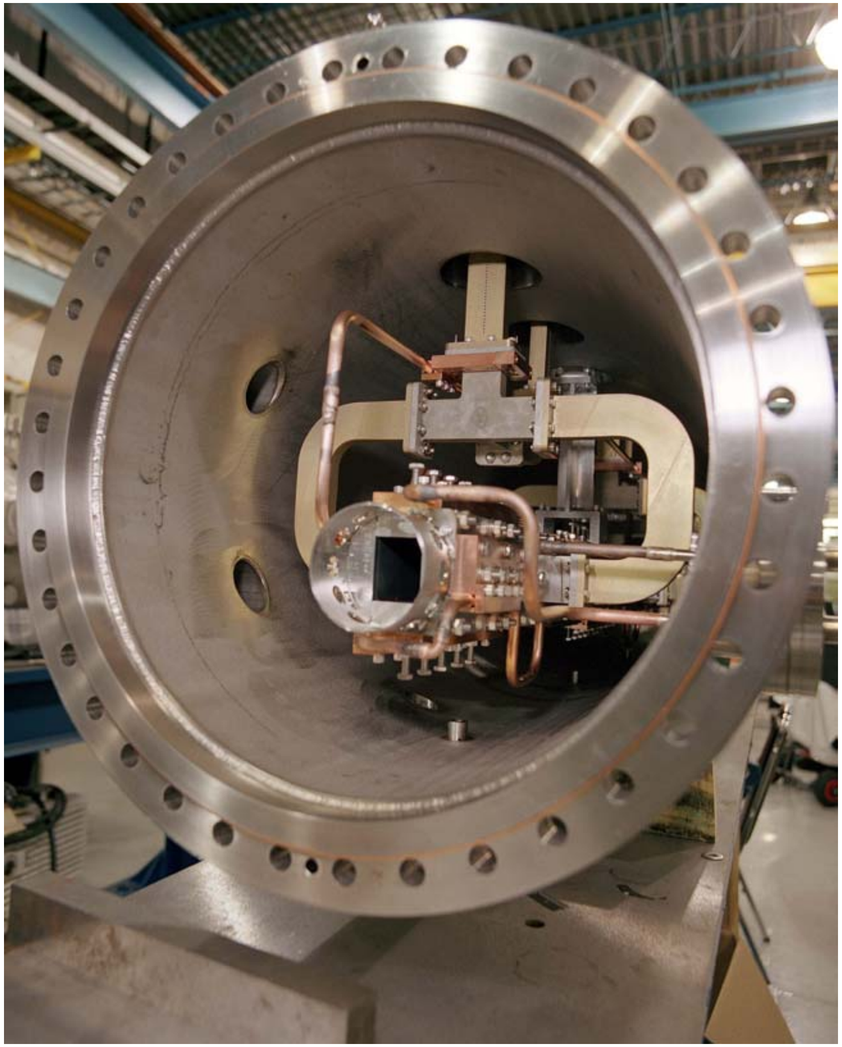
Antiproton Stacking Process

- Debuncher Bunch Rotation
  - Exchange
    - Large Momentum spread of 4% (360 MeV)
    - Short bunches < 1.5 nS (95%)
  - For
    - Small momentum spread of 0.4% (36 MeV)
    - Coasting beam
  - A short bunch lengths on target give small momentum spreads after Debuncher bunch rotation



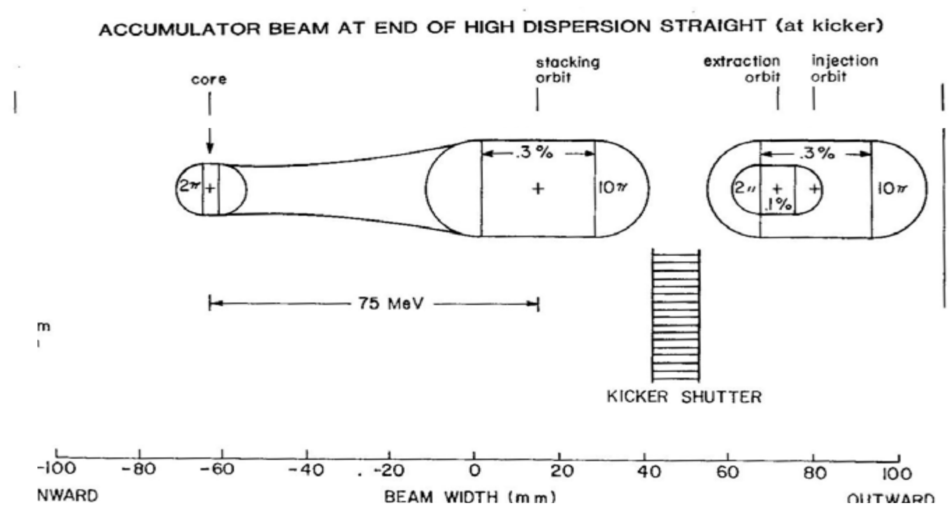
Antiproton Stacking Process

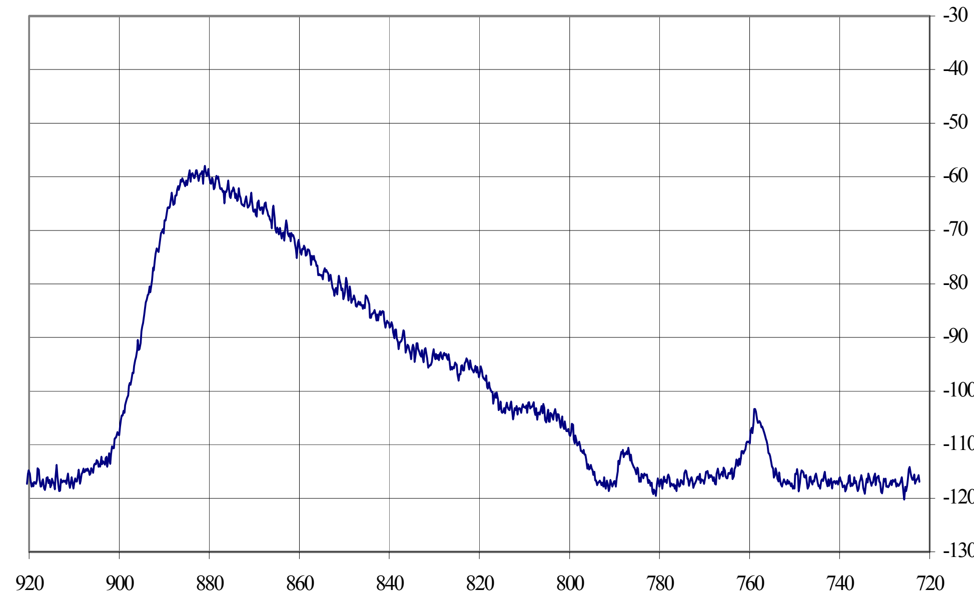
- Debuncher Cooling
  - System Configuration
    - Liquid Helium front end (T_{eff}=30K)
    - Bandwidth = 4-8 GHz Subdivided into 4 bands
    - Available kicker power
      - 2400 Watts/ plane (transverse)
      - 4800 Watts (momentum)
  - Cooling Rate Specs.
    - Momentum: 36 MeV to 6 MeV in 1.9 Seconds
    - Transverse: 35π-mm-mrad to 5 π-mm-mrad (95% un-normalized) in 1.9 seconds



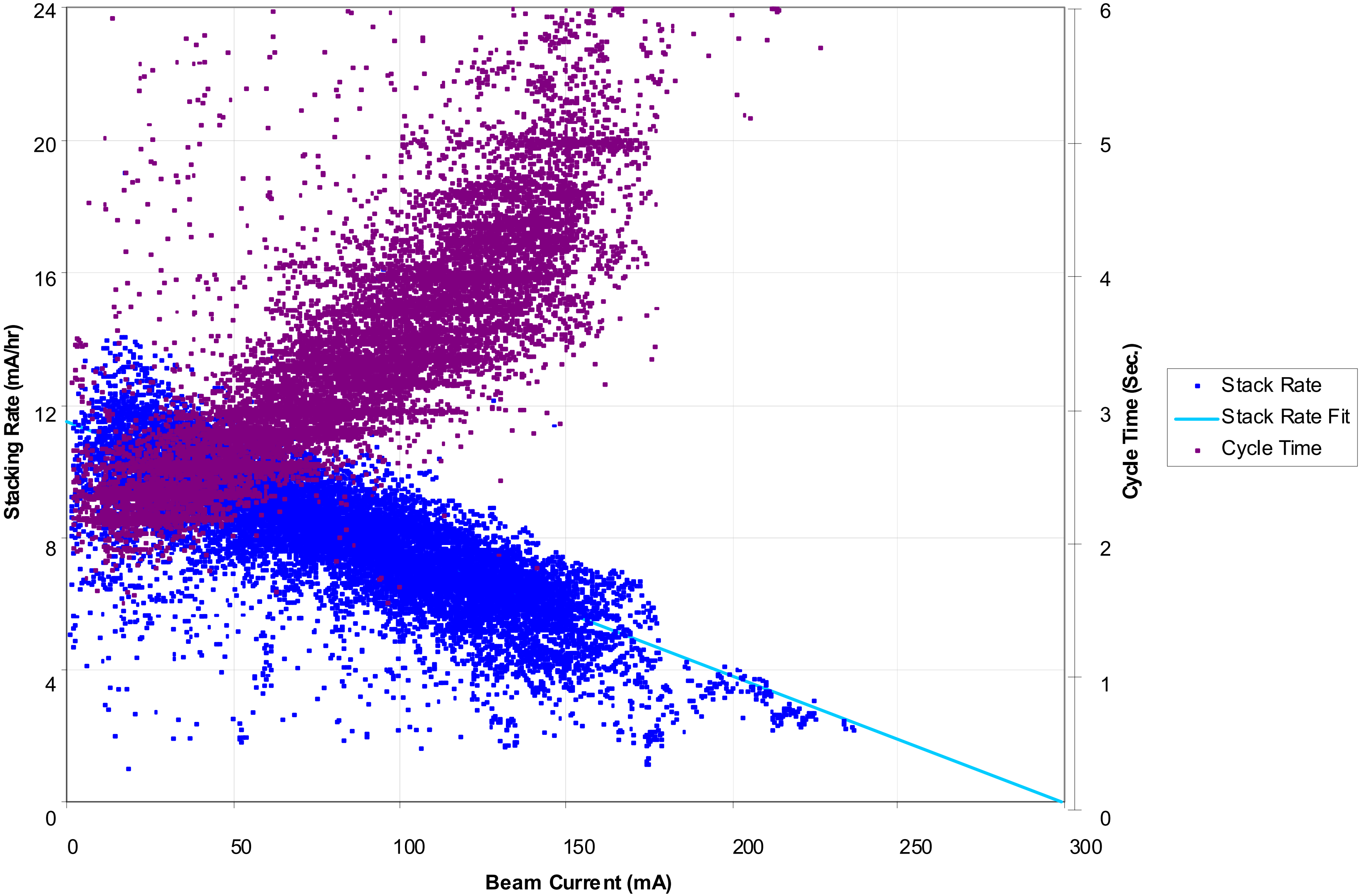
Antiproton Stacking Process

- Accumulator Stacktail Cooling
  - Process
    - Beam is injected onto the Injection Orbit
    - Beam is
      - Bunched with RF
      - Moved with RF to the Stacking Orbit
      - Debunched on Stacking orbit
    - Stacktail pushes and compresses beam to the Core orbit
    - Core Momentum system gathers beam from the Stacktail
    - Accumulator Transverse Core Cooling system cools the beam transversely in the Stacktail and Core



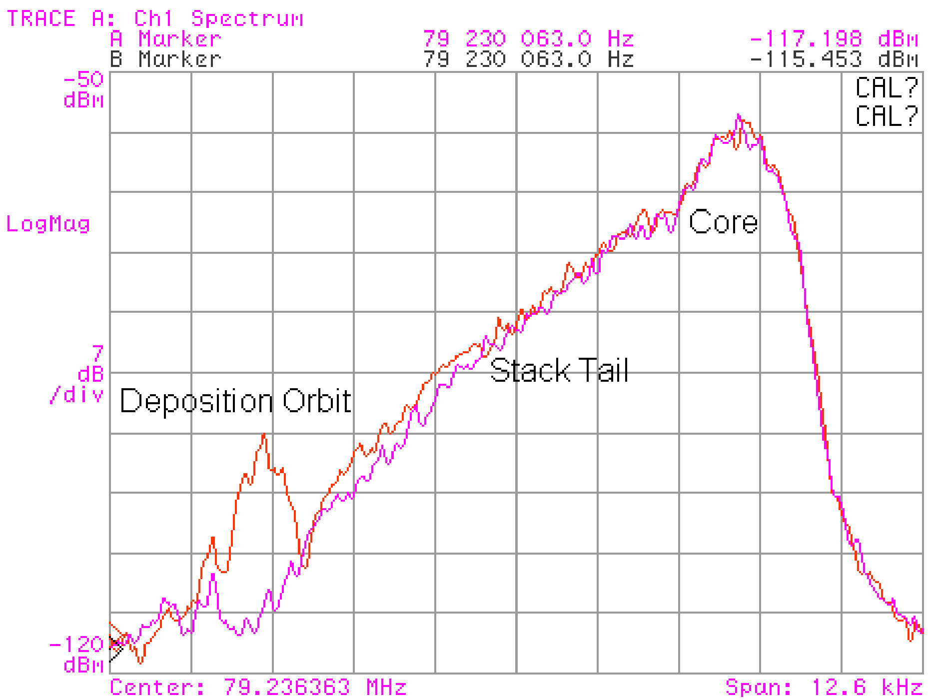


Stack Rate vs Stack Size



Why is the Cycle Time so Slow?

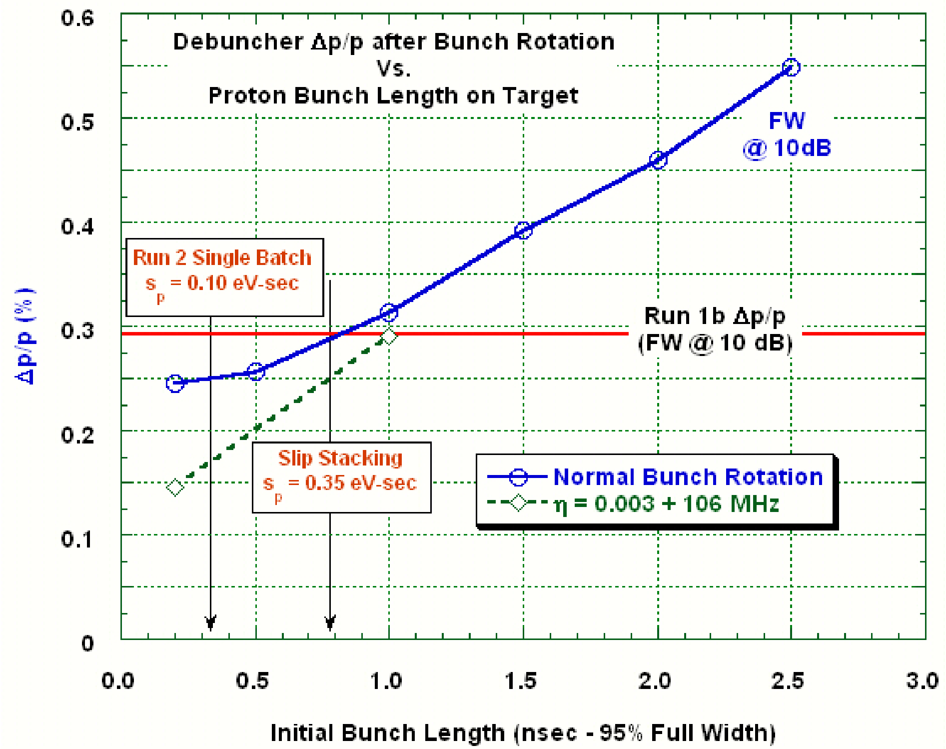
Accumulator Longitudinal Spectrum



- Beam must be cleared off the Stacktail deposition orbit before next beam pulse.
  - The more gain the Stacktail has, the faster the pulse will move.
  - The Stacktail gain is limited by system instabilities between the core beam and the injected beam
  - As the stack gets larger
    - The instability feedback path grows stronger
    - The gain of the Stacktail must be turned down to compensate
    - The cycle time must increase for the lower Stacktail gain

Why is the Cycle Time so Slow?

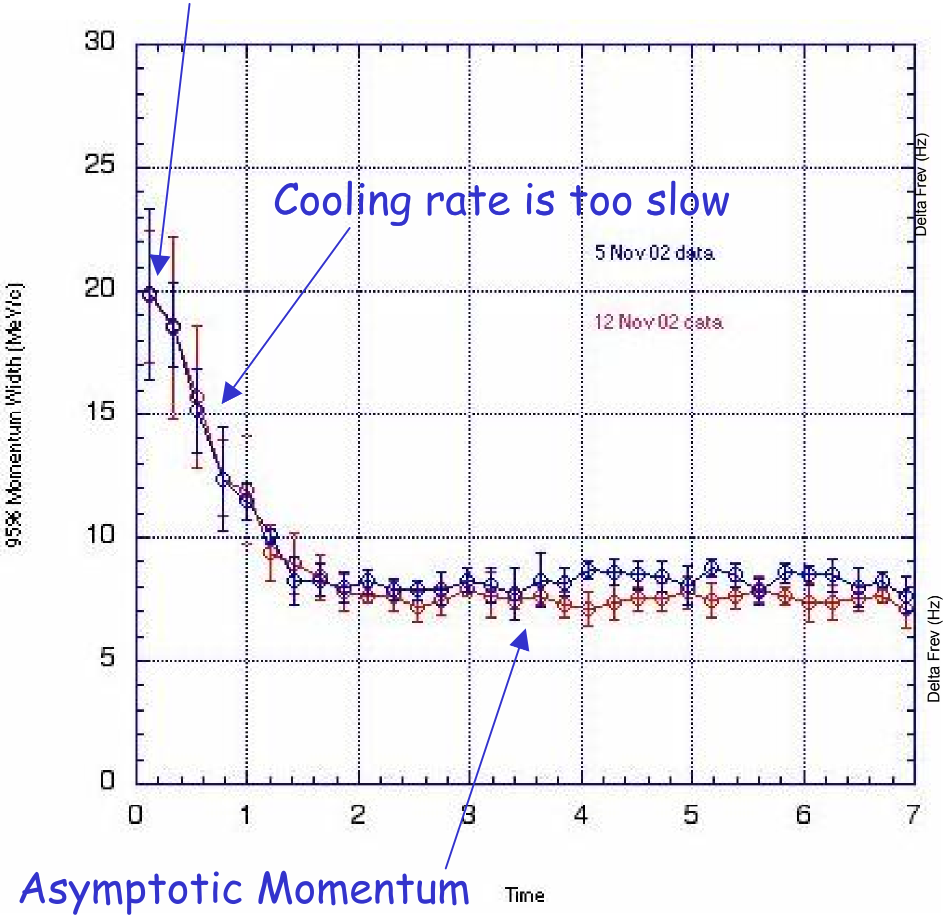
- For a given Stacktail gain, the larger the momentum spread of the injected pulse, the longer it takes to clear the pulse from the Stacktail Deposition orbit.
  - The momentum spread coming from the Debuncher is too large.
    - Bunch length on target
    - Debuncher Cooling rate
    - Debuncher asymptotic momentum



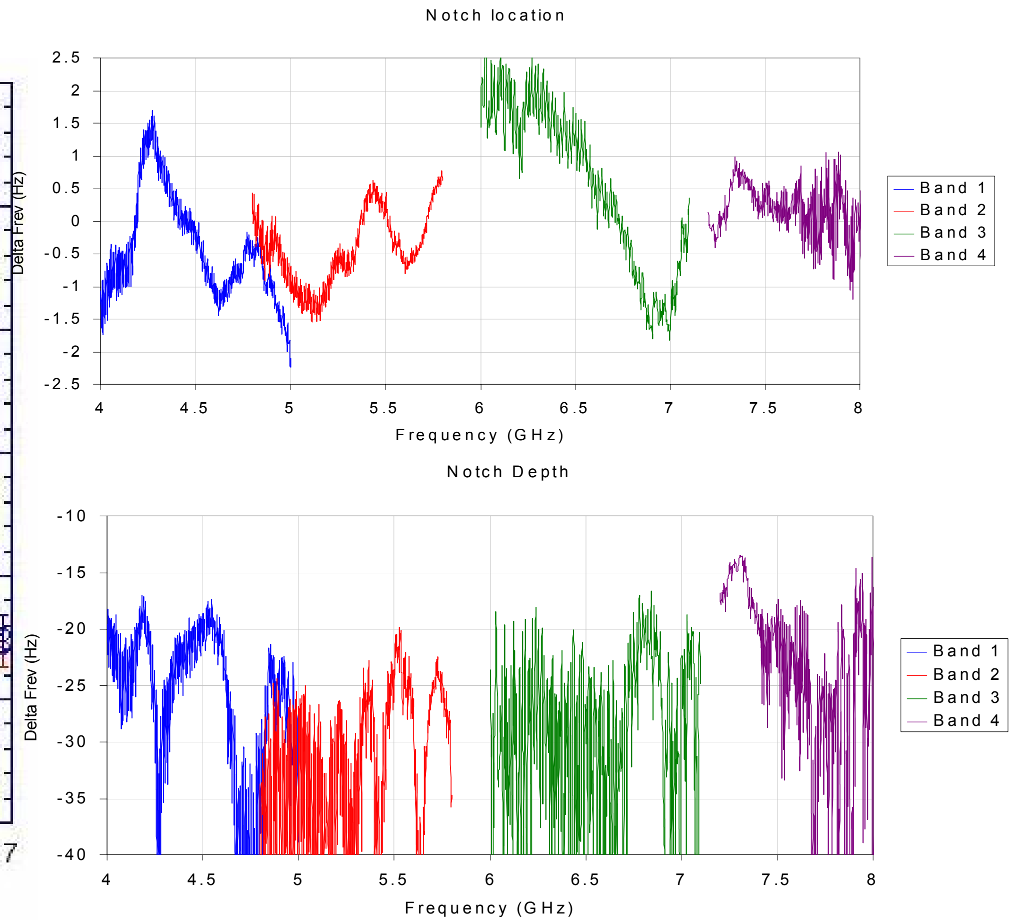
Debuncher Momentum Cooling

Starting Value is too high

Cooling rate is too slow



Asymptotic Momentum is too large



FY03-FY04 Plan

- Debuncher Notch Filter Equalizers Upgrade
- DRF2 barrier bucket noise reduction
- Stacktail Compensation legs
- Stacktail Notch Filter Upgrade
- Stacktail Phase Intercept Adjustments

Future Stacking Plans

- Need "Infinite sink" of cooling the core
  - no 1/N effect
- Electron Cooling
  - Opposite of Stochastic cooling
    - Works well for large stacks
    - Works well for small emittances

Electron Cooling

- Recycler Electron Cooling
  - Every ½ hour an injected batch of 22×10^{10}pbars in 10 eV-Sec and 1.0 π-mm-mrad phase space is injected into the Recycler
    - Transfers between the Accumulator and the Recycler
      - Are done on "event"
        - ~instantaneously
        - No more mini-shot setup
      - A 50% dilution is assumed to occur on each transfer
        - 15 eV-Sec and 1.5 π-mm-mrad phase space
    - Transverse stochastic pre-cooling of the injected batch
      - To bring the transverse emittance of the injected batch within the reach of the electron cooling
      - The injected batch is kept separate from the main "core" by barrier buckets
      - Transverse stochastic cooling systems are "gain gated"
        - Low density injected batch – fast stochastic cooling
        - High density core – slow stochastic cooling

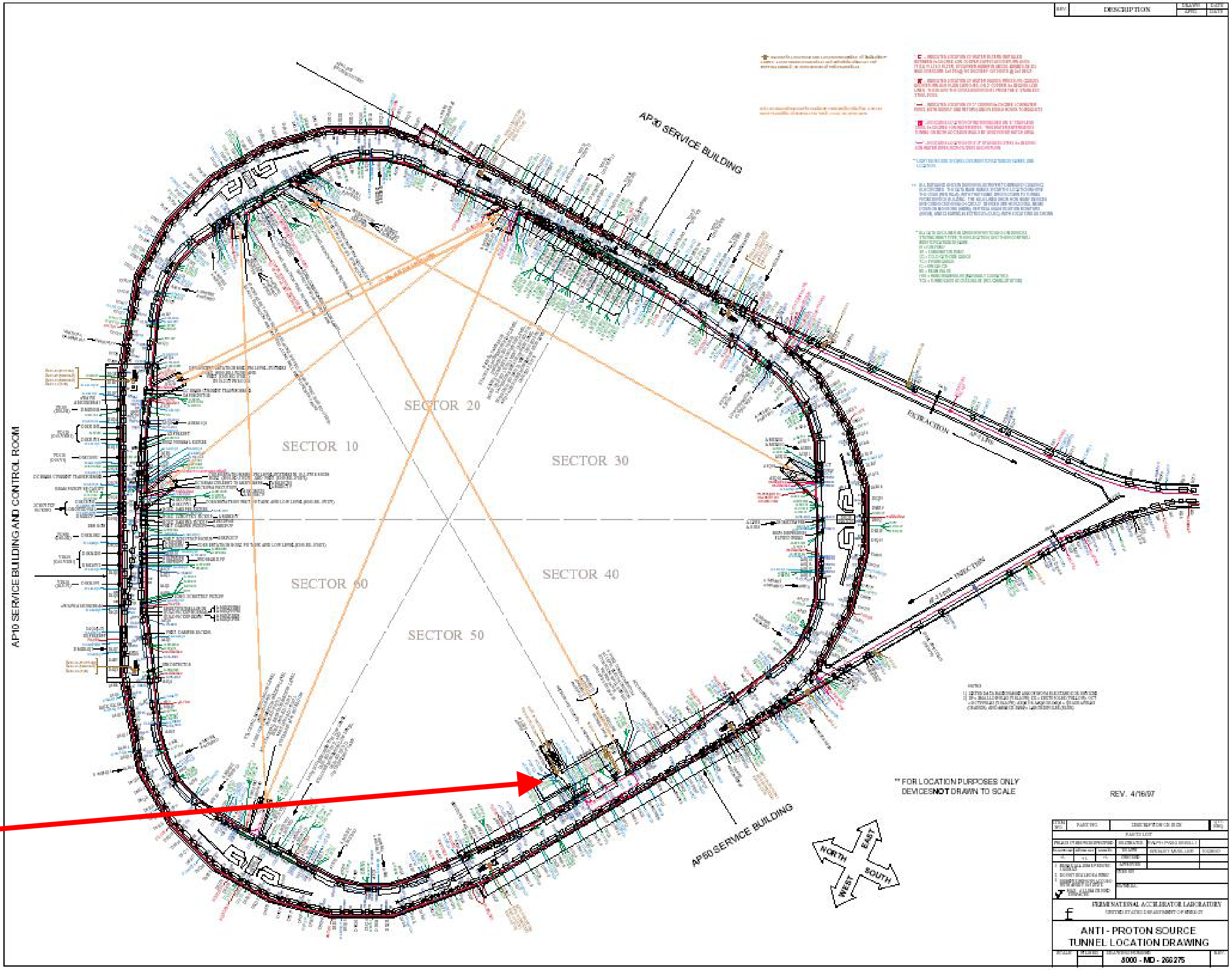
Electron Cooling

- Recycler Electron Cooling
  - Every ½ hour, the previous injected batch is merged into the core with barrier bucket manipulations to make room for the new injected batch
  - The Recycler Core
    - Is cooled mainly with electron cooling in all 3 planes
      - 55eV-Sec/hour
      - 0.24π-mm-mrad/hour
    - Weak transverse stochastic cooling for high amplitude particles
    - Intra-beam scattering (IBS) is "shut-off"
      - Recycler
        - operates below transition
        - has low dispersion
        - has smooth lattice functions
      - The Core is squeezed with barrier buckets so that it occupies only 20% of the machine circumference
      - The transverse emittance is cooled to less than 0.3π-mm-mrad (95% un-normalized) so that the beam temperature in all 3 planes is equal

Electron Cooling

- What happens if the Recycler never "converges"?
- Install Electron Cooling in the Accumulator AP50 Pit
  - A50 Straight Section was used for the E835 detector
    - Straight section no longer used for anything
      - Large pit beneath beam pipe (~4ft below floor level)
    - Counting room no longer used
    - AP50 Drop hatch available
  - 15 meters of straight section between Q1's
    - Zero dispersion
    - Lattice functions could be modified with Q1,Q2,Q3 settings

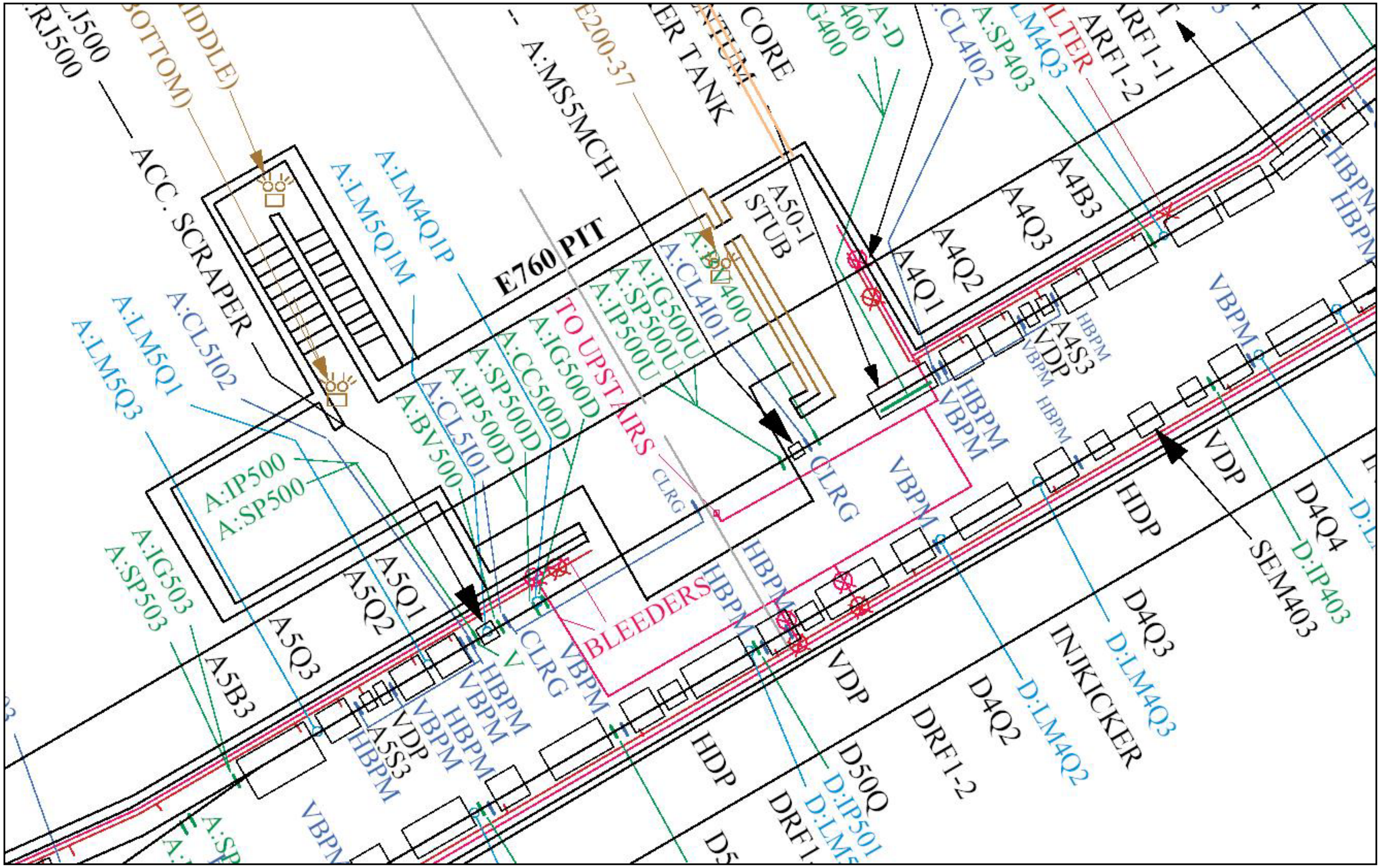
Accumulator Electron Cooling



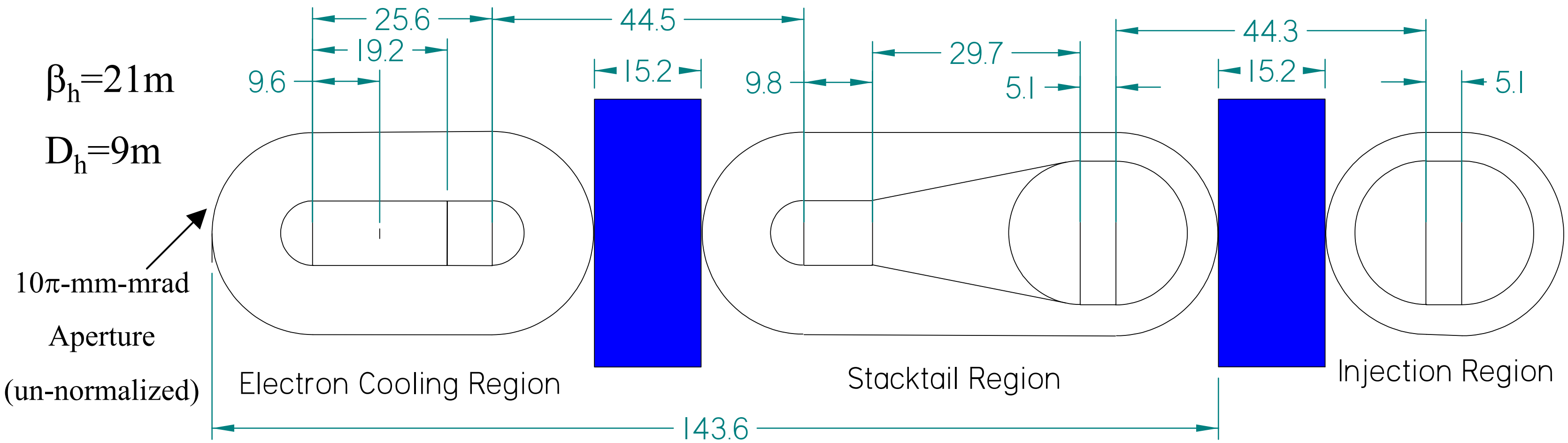
AP50

Pit

AP50 Pit


E760 PIT
A50-1 STUB
ACC. SCRAPER
A:MS5MCH
TO UPSTAIRS
BLEEDERS
A:IP500
A:SP500
A:IG503
A:SP503
A:LM5Q3
A:LM5Q1
A:CL5I02
A:LM5Q1M
A:LM4Q1P
A:BV500
A:CL5I01
A:IP500D
A:SP500D
A:CC500D
A:IG500D
A:IP500U
A:SP500U
A:IG500U
A:CL4I01
A:CL4I02
A:SP403
A5Q1
A5Q2
A5Q3
A5B3
A5S3
A4Q1
A4Q2
A4Q3
A4B3
A4S3
D4Q4
D4Q3
D4Q2
D50Q
DRF1-2
ARF1-1
ARF1-2
INJKICKER
SEM403
D:IP403
D:LM4Q3
D:LM4Q2
D:IP501
HBPM
VBPM
VDP
HDP
CLRG
CORE

Accumulator Electron Cooling



- Accumulator Aperture would be Divided into 3 Regions
  - 208 mm required for 10π-mm-mrad Aperture

Accumulator Electron Cooling

- Advantadges
  - Machine circumference
    - 7x smaller than Recycler
  - No Rapid transfers
    - No beam loss
    - No transverse emittance dilution
    - No longitudinal emittance dilution
    - No waiting for transfer
  - Electron cooler can be placed closer to ring
    - 8 GeV beam only in Accumulator
    - Shielding requirements much less
  - Accelerator Performance
    - Vacuum
      - Ring Size
      - Equipment
        - Pumping speed
        - Bakeout system
    - Aperture
    - No Main Injector ramps to contend with

- Disadvantadges
  - Stacktail Betatron cooling
    - Pickup design is tricky
  - Cooling section length
    - Recycler -> 20 meters
    - Accumulator - > 12 meters
  - Available longitudinal phase space
    - Drag force of electron cooling on Stacktail beam